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EVAPOR - ION PUMP

Evapor-ion high vacuum titanium pumps described first by American authors [1,2,3] attract attention thanks to the absence of working liquid and the possibility of avoiding cold traps.

The pump described below is similar to the American models, but is notable for the design of evaporator and ionizator. Titanium evaporation is going on from the surface of a liquid titanium drop. This moment eliminates deterioration of the evaporator with liquid titanium and allows to evaporate sufficient amounts of titanium without replacement of evaporator.

For the gas ionization the pump has a simple design of ionizator without grids which may be covered with condensed titanium. The ionizator is like a big magnetron gauge [4], but has a supplementary hot cathode which allows the pump to work at low pressures.

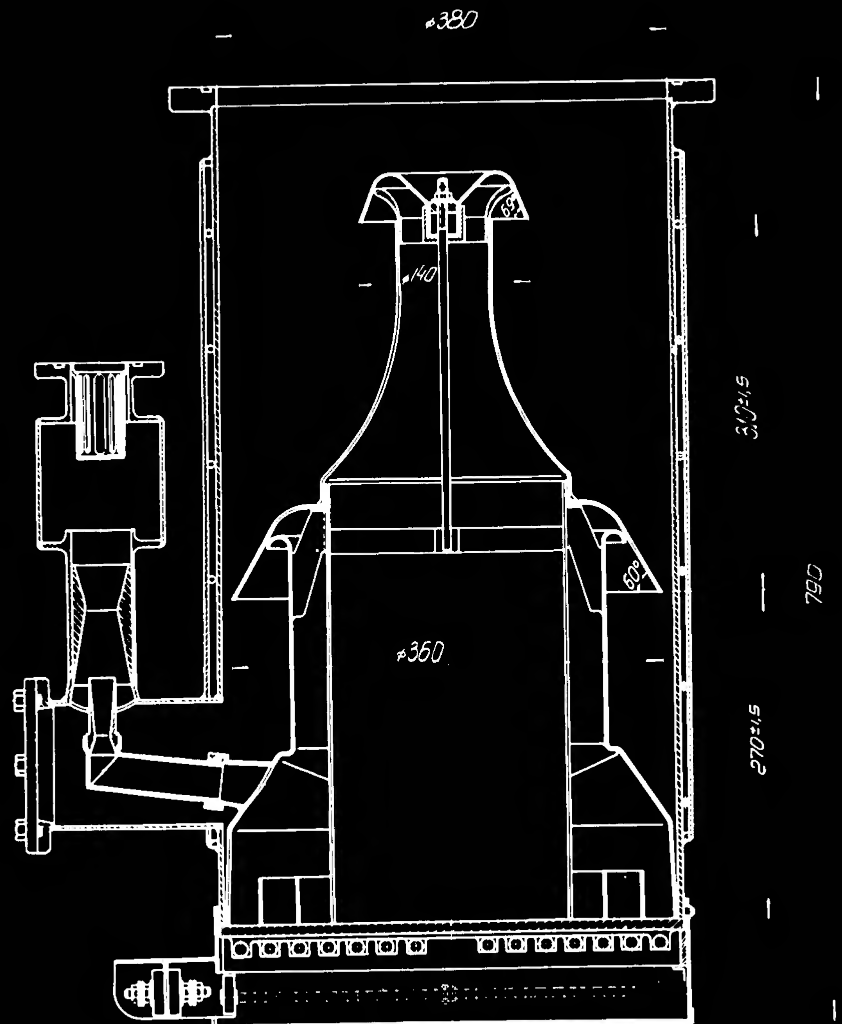

FIG. 1. The sketch of the high vacuum oil-vapour pump with a pumping speed of 5000 lit/sec.

In the pumps of a like design there always exists a certain fractionating of the operating oil during the working process. It occurs because of the steam oil flow which getting on to the cooled walls of the housing condenses there. Then the condensate at first flows down to the periferal zone of the boiler and only from there penetrates

into the central zone which feeds the upper high vacuum nozzle with vapour. In the given pump the fractionating is intensified.

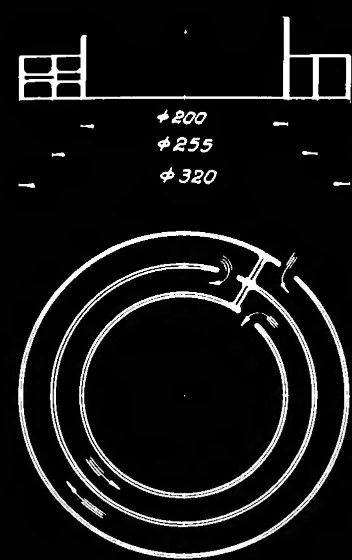

FIG.2. The sketch of the fractionating ring device of the 5000 lit/sec pump

At the bottom of the vapour tube there is a ring device (Fig.2) intended to speed up the process of the oil fractionating.

The intensification of the above process improves the ultimate vacuum and shortens the time of its reaching (Fig.3). It is experimentally found that the intensification of the oil fractioning leads to the decrease of the oil vapour flow from the pump to the evacuated vessel. For example,

a big pump having a speed of 25000 lit/sec with the ring fractionating device has an oil migration amounting to [illegible] cm^3/hour and without such device . $10cm^3$/hour.

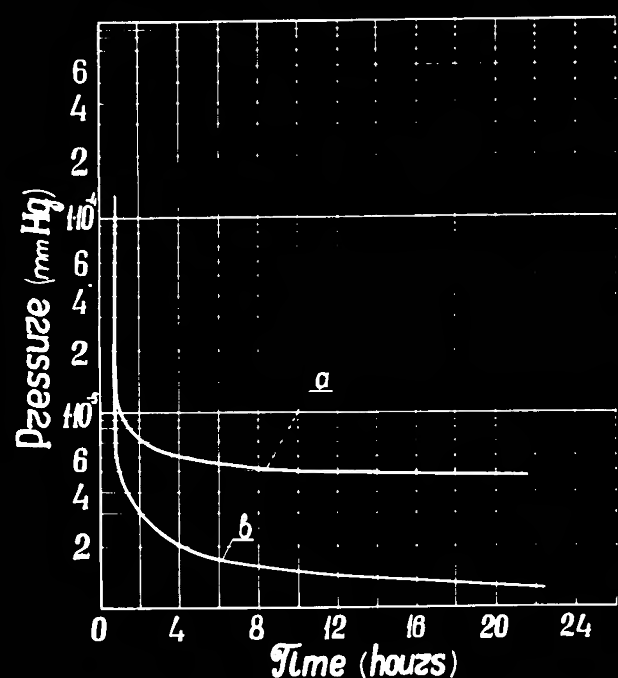

FIG.3. The curve of ultimate vacuum reaching

FIG.4. A model of oil catching device to be placed above the pump upper nozzle

The oil catching device shown in Fig.4 is a cone cap with a water cooling pipe soldered from the outside. The cap is fixed on the steel flange having outside two nipples for connecting it to the cooling system. When assembled with the pump the cap covers the upper nozzle (Fig.5)

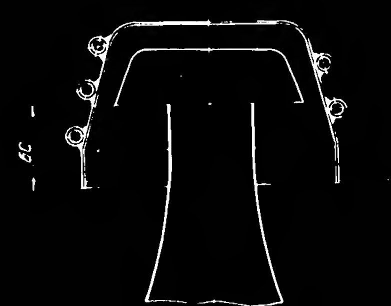

FIG.5. The mounting sketch of the oil catching device

The functioning of the oil catching device is based on the following principle: the velocity of the vapour flow behind the nozzle has components perpendicular to the nozzle axis. Therefore, a part of the vapour flow contains some lines of vapour current $\Psi_i - \Psi_n$ directed to the side opposite to the gas flow. This portion of the vapour flow almost without disturbing the pumping is the main source of the vapour flow of the operating fluid penetrating into the evacuated vessel.

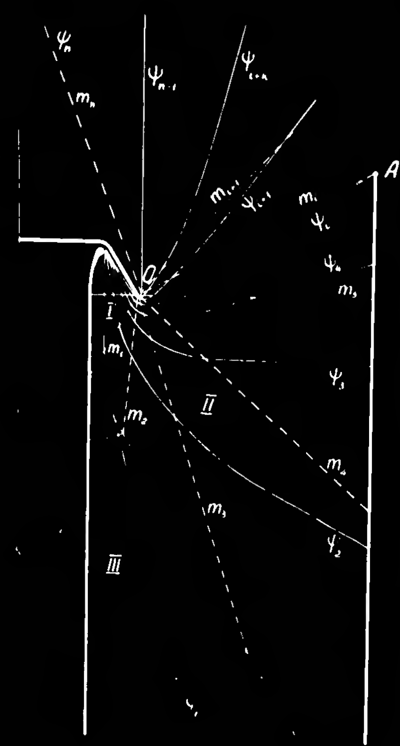

FIG.6. Diagrammatic representation of the vapour flow from the nozzle of the high vacuum diffusion pump

The cooled conc cap of the vapour-catching device is immersed into the flow so as to intersect the backstreaming current lines. The part of the inlet section of the pump additionally shadowed with the cap is so small that it does not cause any considerable decrease of the pump speed (10+15%). This together with the simplicity of the design and making shows the advantages of this device as compared to the known ones.

Model oil-catching devices from 10^2 to 10^3 times decrease the oil flow from the pump.

The ultimate vacuum reaching is approximately 2.10^{-6}mm mercury. In other words the effective pumping speed equals

zero. However, sometimes it is necessary to have a better vacuum than 2.10^{-6}mm mercury. Then a cold trap is added to the pumping unit. The ultimate vacuum reached with the addition of the cold trap which is cooled with liquid nitrogen ($t = -193^{0}C$) improves respectively and reaches 10^{-7}mm mercury.

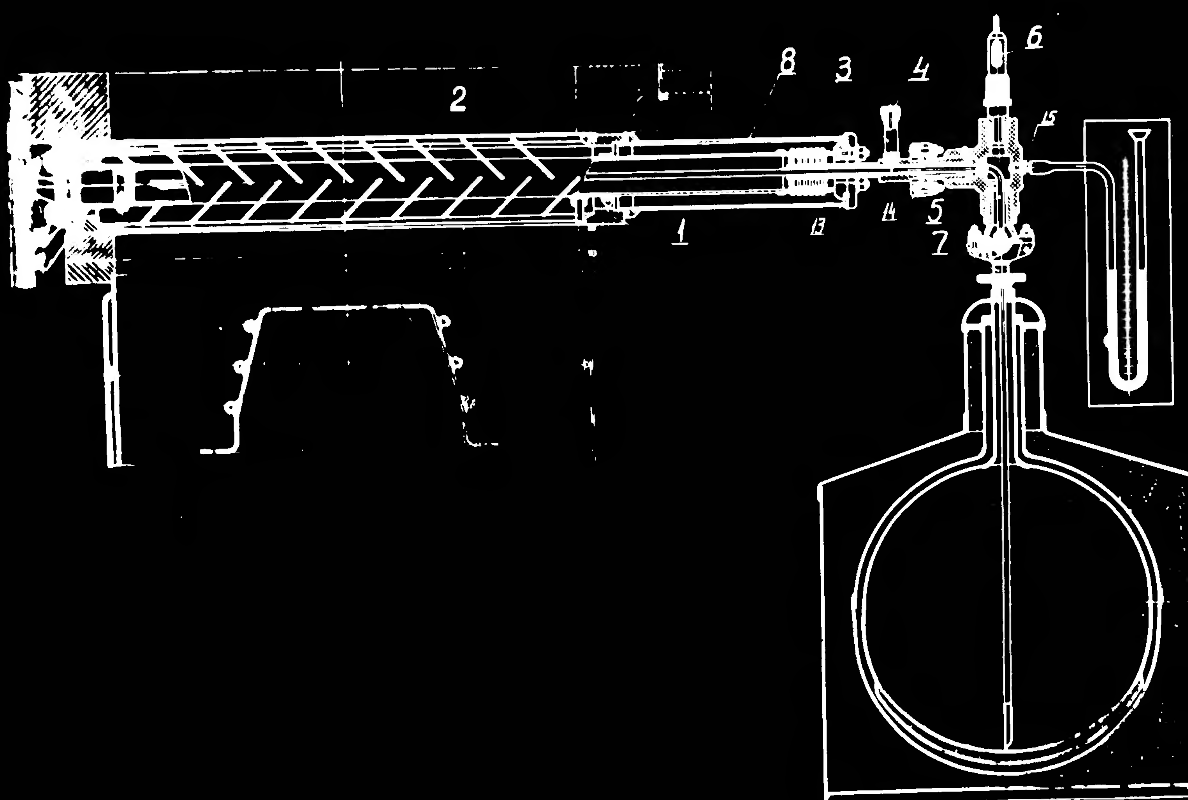

FIG.7. The cold trap cooled with liquid nitrogen.

The trap (Fig.7) represents a set of baffle plates overlapping the pump inlet section and answers the demands of an optical barrier. Shown in Fig.7, a relative displacement of two rows of the baffle-plates with a simultaneous enlargement

of the space between them as compared to the usual, allows to increase the pump conduction up to 25-30%, depending on the area of the overlapped channel and at the same time to maintain the optical barrier.

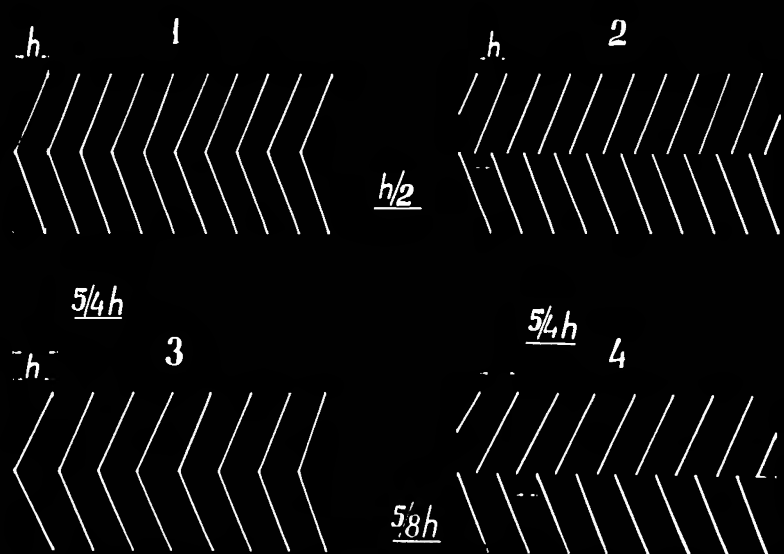

FIG.8. The sketch of constructing the baffles of the increased conduction

1 - Commonly used baffle plates without optical paths;

2 - Displaced baffle plates without optical paths with the same space between the plates;

3 - Baffle plates with optical paths and an enlarged space as compared with the usual;

4 - Displaced baffle plates with no optical paths and an enlarged space.

The sketch of constructing such baffles with increased conduction is given in Fig.8.

Nitrogen is supplied to the central tube of the trap (Fig.7) by means of the bent feeding pipe (5). The vertical part of

it passes through the plug into the vessel with nitrogen. Under the influence of the overpressure produced in the vessel by nitrogen evaporation, the nitrogen through the bent pipe comes into the central pipe and evaporates. Then it vapors through the adjusted aperture (4) [redacted] volatilizes into the atmosphere.

The safety valve (6) of the feeder and adjusting outlet aperture (4) allow to maintain the vessel pressure and nitrogen consumption constant. The outlet throttle and safety valve being correctly mounted, the liquid nitrogen sputtering is eliminated and nitrogen consumption becomes negligible.

The trap together with the feeder allows to supply liquid nitrogen to the trap directly from standard Dewar vessels or tanks used for its transportation.

If a centralized liquid nitrogen feeding of a considerable number of cold traps is necessary as, for example, in the pumping units of accelerators of great extension, each trap can be provided with a separate small-size liquefyer (Fig.9). The latter is fed from a common compressor with gaseous nitrogen (air) compressed up to 200 atm. Liquid nitrogen formed at the liquefyer nozzle goes directly to the central part of the trap where it evaporates. The place of the liquid nitrogen formation and consumption being the same, the liquid nitrogen loss becomes negligible.

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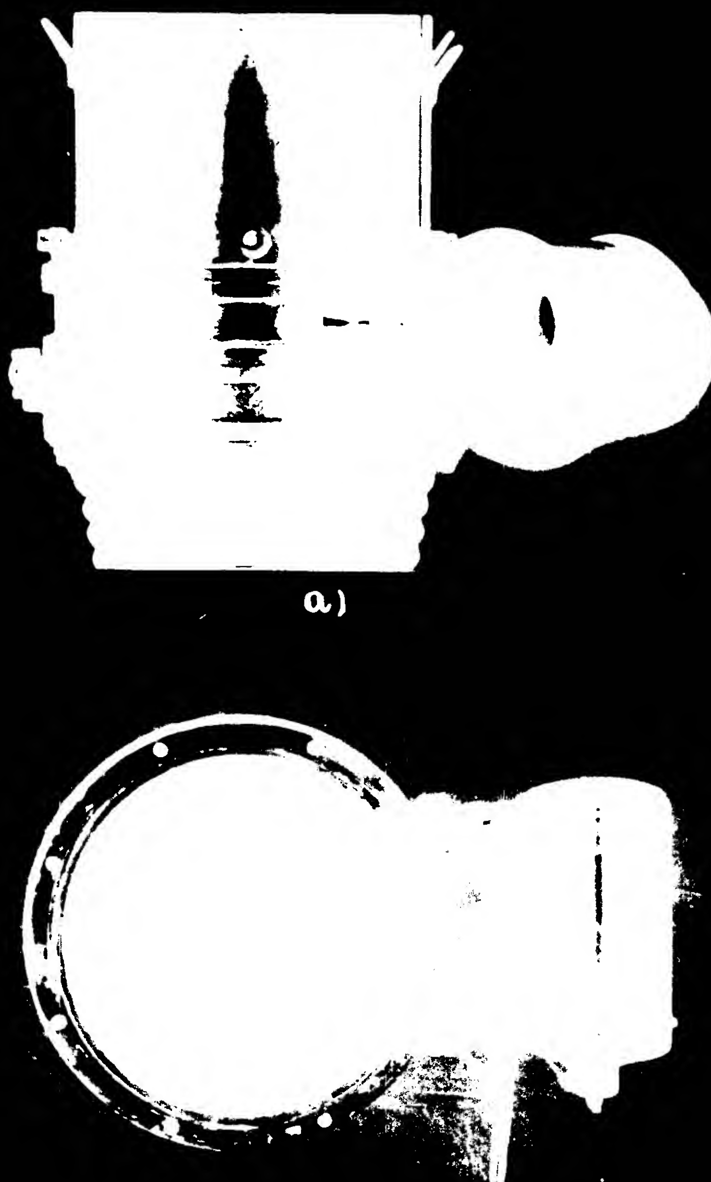


a)

b)

FIG.9. Small-size liquefyer

(a) mounted on a pumping unit

(b) assembled with a trap

Distributing the gaseous compressed nitrogen among the pumping units by means of small diameter pipes is much easier and more economical than the liquid nitrogen distribution the loss of which in intermediate tanks and volumes is very great. For example, the loss of nitrogen in 100-meter isolated vacuum piping amounts to about 50%.

The external view of a model pumping unit is shown in Fig.10. It consists of a high vacuum pump with a hydrorelay, associated with the heater, an oil catching device, a high vacuum gate, an intermediate head to be connected to the chamber and a wheeled frame.

a)   b)

FIG.10. A model pumping unit based on the 5000 lit/sec high vacuum pump

(a) without a cold trap;

(b) with a cold trap fed by liquid nitrogen from a standard Dewar vessel.

A mercury vapour pumping unit is mounted in the same way.

In the mercury vapour units usually in front of the cold trap (t = -192,6°C) the second trap (t = -38,6°C) is placed. (See, for example, Hugh R. Smith, The Technology of Large Mercury-Pumped Vacuum Systems, Vacuum Sumposium Transactions, 1954). However, using the above described water-cooling vapour-catching cone cap makes this second trap unnecessary.

FIG. 11. The vapour-catching cap in the mouth of a mercury-vapour pump

The vapour-catching cone cap mounted in the mouth of the mercury-vapor pump with a speed of 5000 lit/sec is shown in Fig.11. On the inner surface of the pump housing one can clearly see a layer of mercury the upper boundary of which is on the level of the cap cut.

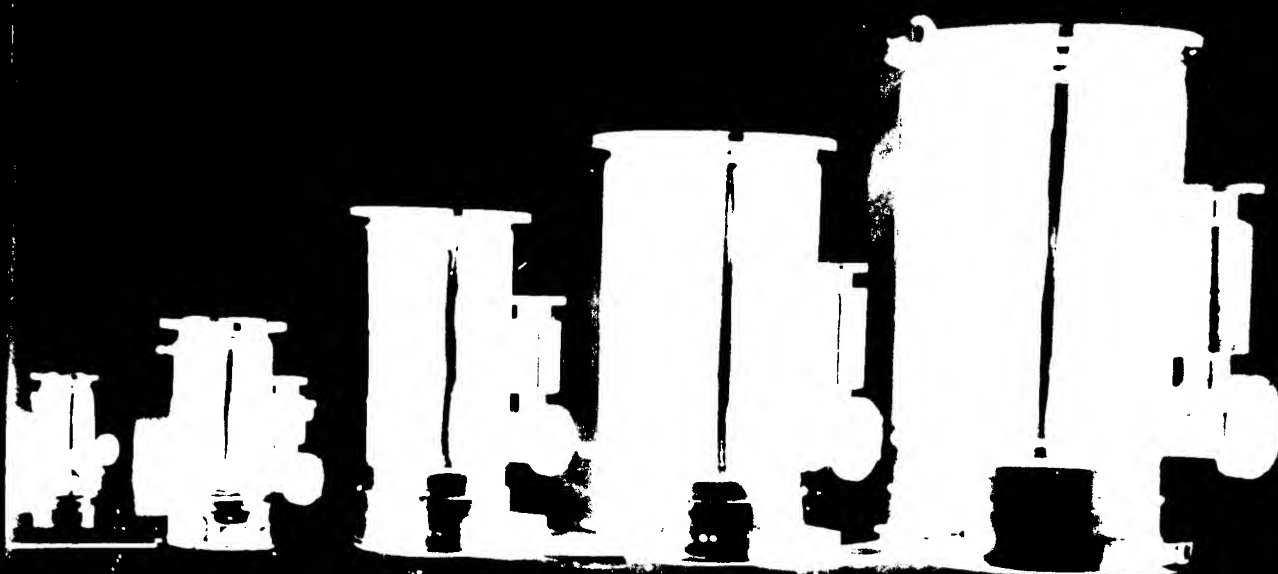


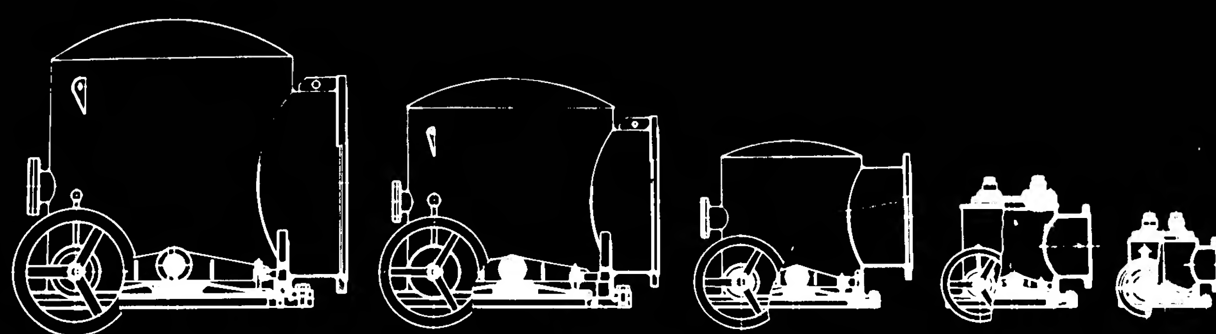
FIG.12. A series of high vacuum oil vapour pumps with a pumping speed of 100, 500, 2000, 5000, 8,000 lit/sec.

Oil and mercury pumping units with different pumping speed (from 100 to 25000 lit/sec) are being used. Their design is like the described above.

Fig.12 demonstrates a series of high-vacuum oil-vapour pumps with a pumping speed from 100 to 8000 lit/sec, and Fig.13. shows the vacuum gates used in the units with these

pumps. The gates can have both manual and remote control.

a)



b)

FIG. 13. High vacuum gates for a series of the pumps with a speed of 100, 500, 2000, 5000 and 8000 lit/sec.

(a) direct;

(b) with an intermediate elbow socket.

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The main technical data of oil-vapour pumps are given in literature (see Savinsky, K.A., "Zavodskaya Laboratoria" No.5 (1955); High Vacuum Equipment, Vacuum, v.IV, No.3, 326 (1954).

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HIGH VACUUM PUMPS AND UNITS FOR ACCELERATORS

High vacuum pumps for accelerators should be provided with some special devices to prevent the vapour migration of the operating fluid (oil or mercury) from the pumps into the vacuum chambers. These special devices should function without cutting down the pumping speed in the range of the order of 10^{-6} mm mercury.

The following report gives the description of the specific characteristics of the devices which are used in the high vacuum pumps for the accelerators designed in the USSR.

Among the routine oil_vapour pumps the pump with a diameter of 380mm and a pumping speed of 5000 lit/sec is the most common. The construction of this pump closely resembles the pump used for the 10 BeV synchrophasotron (Fig.1).

There are two high vacuum-stages and a final jet stage in this pump. The latter being able to withstand the back pressure of more than 100 μ mercury, the high vacuum pump can be directly connected to the forevacuum.

Pump Arrangement

Fig.1 represents the section of evapor-ion pump.

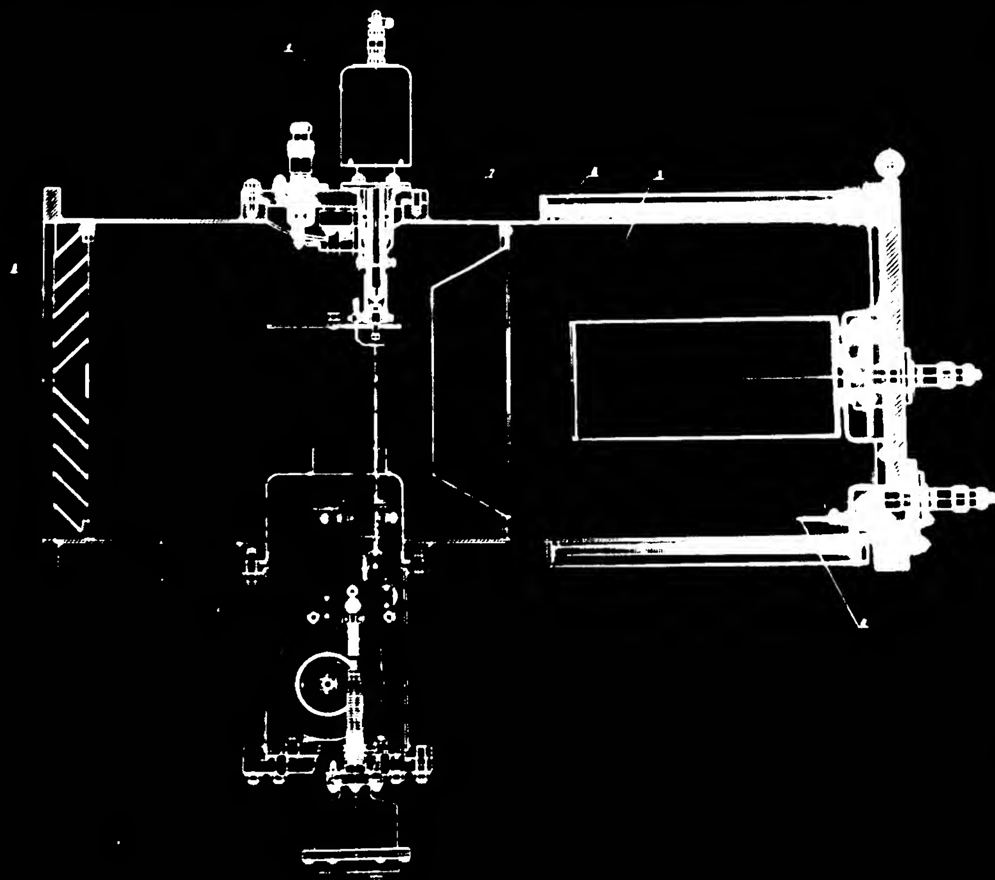

Fig.1. The section of pump

1 - evaporator; 2 - feeder; 3 - anode of ionizator; 4 - cathode of ionizator; 5 - housing; 6 - lattice screen; 7 - baffle; 8 - solenoid.

The pump housing is a stainless-steel tube with water cooling. The upper part of the housing contains the evaporator. The feeder with the titan wire stock is placed under the evaporator; the evaporator and the pump housing serves as its outer electrode. There is a baffle between the ionizator and the evaporator to screen the latter

from the electric field. The baffle has a ring cut to pass the vapor.

The pump inlet is closed by means of a removable lattice screen which prevents titanium migration into a column to be exhausted. Conventional vacuum rubber is used for tightening seals.

The titanium evaporator (Fig.2) represents a molybdenum rod fastened in a cooled holder with a titanium drop melted on the rod top.

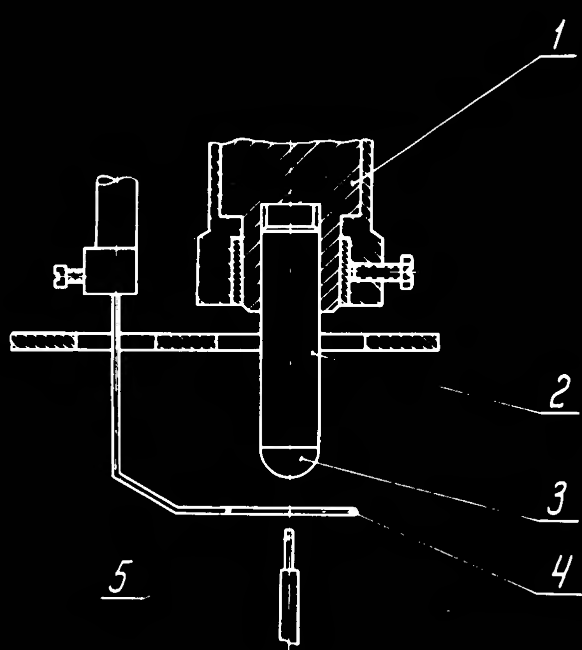

Fig.2. Scheme of evaporator

1 - cooled holder; 2 - molybdenum rod;
3 - titanium drop; 4 - cathode;
5 - titanium wire.

The tungsten wire ring cathode placed under the drop is used for heating the drop by means of electron bombardment.

When at work only the lower part of the drop is maintained in liquid state. At the place of contact with the rod the drop remains solid because of sufficient heat dissipation through the rod.

The titanium wire is fed from below into the liquid part of the drop. The power of heating is to be kept constant to realize mentioned condition. The power stabilization presented some difficulties.

The evaporation rate from the titanium drop lies in the range 4 + 10 mg/min.

Instead of the molybdenum rod with a melted drop, a zircon rod can be used, its lower part being kept in liquid state. In that case the evaporation from the liquid solution titanium-zirconium rates 0 + 3 mg/min.

The evaporator life is defined according to the rate of contamination penetrating into the drop from the wire or from the gaseous phase. At usual conditions the evaporator life lasts up to 500 hrs. Over 150g of titanium can be evaporated during that period of time.

<u>The feeder</u> accomplishes the intermittent feed of wire into the evaporator. There is a danger of wire jamming in the guiding tube due to filling up of the tube orifice with vaporized titanium. That danger is diminished owing to the use of the drop evaporated at constant rate.

The feed of wire ø 0,5mm is achieved by means of rollers, one of which being rigidly coupled to a ratchet, acted upon by a push-rod. The push-rod is lifted by an electromagnet operated periodically by a timer. The wire feed amounts to 5mm per one pulse. The guiding tube is put aside from the evaporation spot for the time periods between pulses and is practically not covered with titanium. The tube is set under the drop only for feed and is at once taken back.

The vaporization rate of titanium being 5mg/mm the tube remains under the drop in the deposits some 1/30 + 1/20 part of full working time.

The feeder gives out more than 150g of vaporized titanium.

The ionizator is designed as a separate block of the pump. This block represents a cylindrical magnetron with reversed polarity. As a conventional magnetron this device allows to get a considerable electron density in the discharge gap, but contrary to the usual magnetron the positive ions are pushed outside.

The walls of the housing covered with titanium serve as an outer negative electrode. There is a cylindrical anode under high potential mounted along the axis of the ionizator.

A small hot cathode placed near the pump walls acts as an electron source. The ionizator is surrounded with an outer coil creating longitudinal magnetic of the order of 100 oersted.

The discharge current of the ionizator does not exceed 1 - 2 mA at 10 kv of anode potential in the working pressure range. Power dissipated from the anode amounts to 10 - 20 watts respectively.

Working characteristics of pump

The evapor-ion pump is tested with a test dome which is connected to the inlet pump socket and contains gauges and a leak valve.

Preliminary experiments confirmed data [2,5] concerning the high pumping speed(of the order of $10^3 \div 10^4$ l/sec) of some gases, s uch as: hydrogen, nitrogen, oxygen, carbon mono- and dioxide.

The speed of water vapor pumping is found to be of the same order of magnitude.

Vacuum characteristics of the pump

1. Starting fore-pressure ... 1.10^{-4} mm Hg
2. Ultimate pressure ... 3.10^{-8} mm Hg
3. Time of reaching vacuum 10^{-7} mm Hg (from pump switching on) ... $10 \div 15$ hr
4. Pump speed at pressure 10^{-6} mm Hg
   - (a) hydrogen . . . . 5000 l/sec
   - (b) nitrogen . . . . 2000 l/sec
   - (c) air . . . . 1500 l/sec
   - (d) argon . . . . 50 l/sec

Figs.3,4,5 represent the pumping speed of nitrogen, hadrogen and argon versus pressure at the rate of titanium

evaporation 5 mg/min.

The curve of speed for hydrogen extends far into the range of high pressures in contrast with a "normal" curve for nitrogen. This phenomenon seems to be connected with high speed of diffusion of hydrogen atoms from the surface into the depth of condensed titanium, the speed of diffusion being compared to that of hydrogen entering the surface.

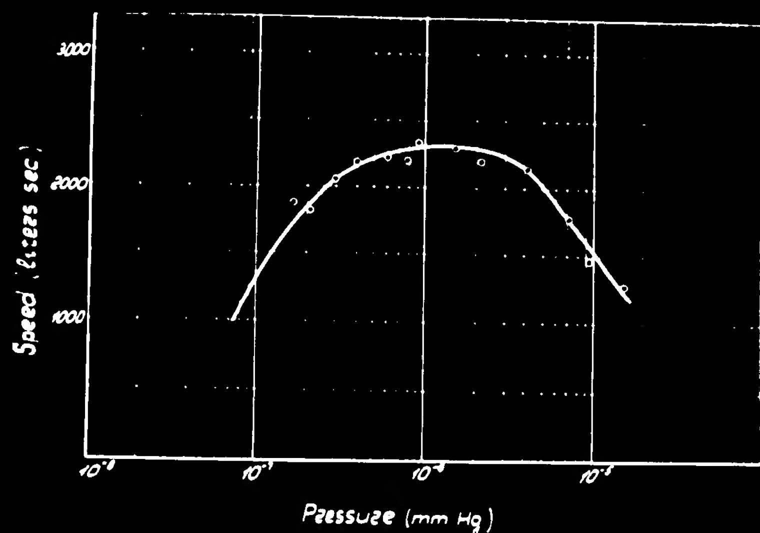

Fig.3. The pumping speed for nitrogen

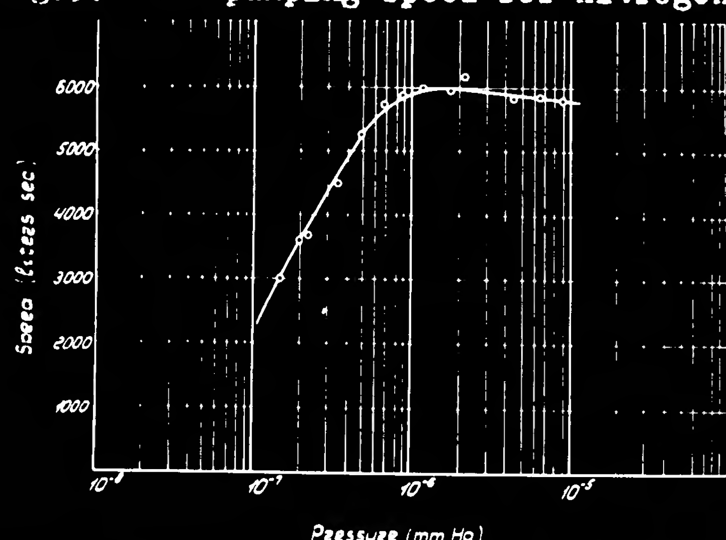

Fig.4. The pumping speed for hydrogen

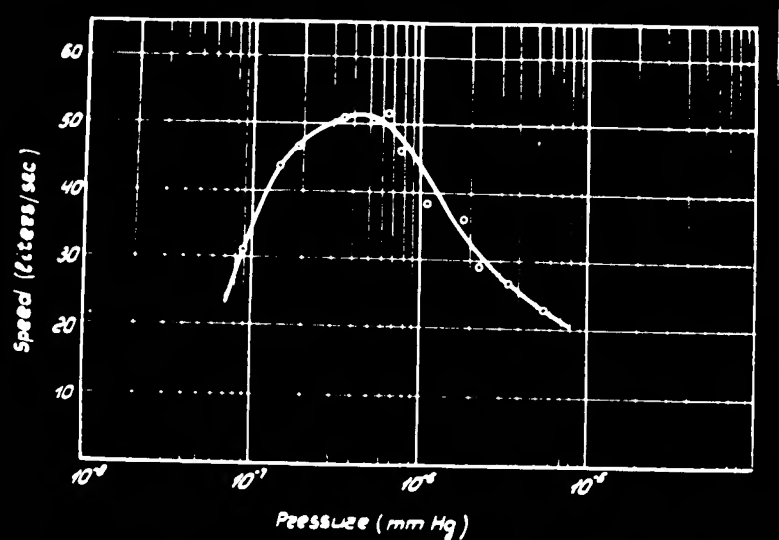

Fig.5. The pumping speed for argon

The above mentioned characteristics show the possibility of using the described evapor-ion pump and similar pump with pumping speeds of 2000 and 20000 l/sec for hydrogen in accelerator vacuum systems.

Evapor-ion pumps appear to be profitable, if a vacuum of about 10^{-7}mm Hg is required without traces of working fluid in the volume to be exhausted.

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